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PRELIMINARY SITE SURVEY REPORT FOR THE FORMER ELZA GATE WAREHOUSE AREA, OAK RIDGE, TENNESSEE

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ABSTRACT

In the early 1940s, the operations of the Manhattan Engineer District (MED) in support of the war effort included the importation and refining of foreign uranium ore. The radium-bearing sludges that resulted from the refining process were stored in warehouses in Oak Ridge, Tennessee, while awaiting further disposition. Later on, other radioactive materials such as tailings, oxide residues, and slag were also stored in the five warehouses. Following the removal of the stored materials to other facilities, the Atomic Energy Commission's Y-12 Plant in Oak Ridge used the warehouses for a period of time before the site was decontaminated and released for unrestricted use under criteria current at that time. However, because guidelines for use of such sites have become more stringent since previous cleanups, and because it is the policy of DOE to verify that such sites are in compliance with current guidelines, a radiological survey was conducted on parcels 1-4 of the property by members of the Measurement Applications and Development Group of Oak Ridge National Laboratory in March 1989.

Survey results show that widespread residual radioactivity from former operations remains on the property, primarily in outdoor soil and as surface contamination on three of the original concrete pads, one of which is inside the present building. Residuals are in excess of the DOE's criteria for cleanup under the Formerly Utilized Sites Remedial Action Program. Since results also indicate that spillover contamination to parcels 5-9 on the property is probable, further surveying of these areas may be appropriate.

PRELIMINARY SITE SURVEY REPORT FOR THE FORMER ELZA GATE WAREHOUSE AREA, OAK RIDGE, TENNESSEE*

INTRODUCTION

In the early 1940s, the operations of the Manhattan Engineer District (MED) in support of the war effort included the importation and refining of foreign pitchblende (high-grade uranium ore). Procurement of the ores was for the purpose of recovering purchased uranium only. The valuable radium-bearing sludges containing precious metals that resulted from the refining process were to be returned to African Metals of the Belgian Congo, the original source and continuing owner of any residual materials. Several warehouses for storing sludges derived from the ores were constructed by the Clinton Engineer Works on a 20-acre tract of land in Oak Ridge, Tennessee, at the intersection of Melton Lake Drive and the Oak Ridge Turnpike at Elza Gate. Figure 1 is a 1943 map of Oak Ridge showing the locations of the warehouses, at least three of which were used for storing radioactive material. The radium-bearing sludge component remaining from refining grades of ore containing >10 percent uranium oxide (U_3O_8) was packed in wooden barrels for storage in the facility. Later on, when stockpiles of incoming ore outgrew the pace of refinement, both high- and low-grade ores were stored on the Elza Gate property. Some tailings, oxide residues, and slag intended for reprocessing were also temporarily disposed of in the warehouses. Paper and burlap bags were initially used to contain low-grade ores. Historical records indicate that, over a period of time, some of the slag barrels in the warehouses had deteriorated, requiring replacement. Insufficient documentation is available to determine exactly when the MED or the Atomic Energy Commission (AEC) ceased using these facilities for this purpose. However, in 1956, approximately 1,024 wet tons of radium sludges from high-grade ores were moved from the Elza Gate warehouses and shipped to the Middlesex, New Jersey, storage facilities. Later, the AEC Y-12 Plant used the warehouses for storage until they were no longer useful to Oak Ridge Operations. Decontamination was performed under guidelines and criteria current at that time and the property was released for unrestricted use. The facilities were sold in 1972 to Jet-Aire, Incorporated, by the AEC.[1] A more recent owner has used the building for fabricating (grinding and welding) metallic air-handling components for large ventilation structures. A private company currently plans to develop the property into an industrial park.

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*The survey was performed by members of the Measurement Applications and Development Group of the Health and Safety Research Division at Oak Ridge National Laboratory under U. S. DOE contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

Guidelines for use of such sites have become more stringent since the previous cleanups. Based on preliminary information provided by Oak Ridge National Laboratory (ORNL) and earlier data collected by Oak Ridge Associated Universities, the entire former warehouse property was authorized for inclusion in the Department of Energy's (DOE) Formerly Utilized Sites Remedial Action Program (FUSRAP) as a medium priority site.[2] The preliminary surveys disclosed levels of residual radioactivity above FUSRAP criteria but below those posing a potential for significant exposure to workers. The radiological assessment survey discussed in this report was conducted, at the request of DOE, by ORNL in October and November, 1988. This survey was also preliminary. Its purpose was to collect sufficient data to determine if each of the four parcels under consideration warranted designation. Once sufficient designation data were collected, the survey of that parcel was generally ended assuming the remainder of the data would be collected during later site characterization.

SITE DESCRIPTION

During the MED era, the complex consisted of five warehouses and possibly other, smaller structures. Access was via a railroad spur southeast of the warehouses and a road entering the property from what is now Melton Lake Drive. The site is divided into nine parcels with a dead-end asphalt road dividing parcels 1-4 from 5-9 (Fig. 2). All that remains of the original structures are five concrete pads located in parcels 1-4. A concrete pad 10,000 ft^2 (900 m^2) from one of the original warehouse foundations in parcel 1 remains as part of the floor of a sheet metal building constructed by one of the private owners. Parcels 2, 3, and 4 each contain a single concrete pad varying in size from 12,000 ft^2 (~1,100 m^2) to 23,000 ft^2 (2,100 m^2). Rings of rust-colored stains crusted over with a yellow residue were observed in scattered areas on the pads in parcels 1 and 2 where 50-gal metal drums had apparently been stored. A construction trailer is situated on the pad in parcel 4 that is also being used for open storage of drums, construction debris, and other materials. Parcels 5-9 south of the road are grassy and barren of broad-leaved species, while areas north of the road not occupied by structures are for the most part, heavily vegetated with trees, shrubs, and woody vines.

SURVEY PROCEDURES

The radiological survey included: (1) measurements of gamma exposure rates at 1 m above the floor surface and at the floor surface at grid locations throughout the building; (2) the determination of direct and transferable beta-gamma and alpha activity levels on surfaces inside the building; (3) a gamma scan at the surface inside the building and throughout parcels 1–4; (4) measurements of direct and transferable beta-gamma and alpha activity levels in selected locations on outdoor concrete surfaces; and (5) the collection and radionuclide analysis of soil samples. A comprehensive description of the survey methods and instrumentation has been presented in another report.[3]

Using a portable gamma scintillation (NaI) survey meter, measurements were determined at the intersections of lines according to a grid system established inside the building. Grid blocks were also scanned to determine ranges of exposure rates. Outdoors, ranges of gamma measurements were recorded by scanning the ground surface. On both indoor and outdoor surfaces where exposure rates were elevated, beta-gamma dose rate measurements and alpha activity levels were determined. Smears were also obtained from selected surfaces to establish transferable alpha and beta-gamma activity levels. In addition, soil samples were collected at increments of 5 or 15 cm from depths of 0 to 51 cm in outdoor areas of elevated gamma levels. All samples were analyzed for radionuclide content.

SURVEY RESULTS

Applicable DOE guidelines for residual radioactivity at FUSRAP sites are summarized in Table 1. Gamma radiation levels measured at 18 areas on the Oak Ridge Reservation (ORR) are presented in Table 2. These data are considered representative of background radiation levels and radionuclide concentrations for the Oak Ridge area and are provided for comparison with the survey results presented in this section. With the exception of measurements of transferable activity, which are reported as net disintegration rates, all direct measurements presented in this report are gross readings; background radiation levels have not been subtracted. Similarly, background concentrations have not been subtracted from radionuclide concentrations in soil samples.

PARCEL 1

BUILDING

Gamma Exposure Rate Measurements

Figure 3 shows the grid system established for surveying inside the building in parcel 1. Five systematic locations in each grid block were selected for readings according to the following array: approximate center of the block (1 reading); approximate center of each quarter block (4 readings). One to five additional measurements were taken in some blocks. Table 3 lists the ranges and arithmetic averages of these multiple measurements by grid block. The ranges of measurements are displayed on Fig. 3. Gamma exposure rates ranged from 5 to 40, and 4 to 200 μR/h, for readings taken at 1 m and at the surface, respectively, with overall corresponding averages of 14 and 30 μR/h. Further direct scanning revealed additional anomalous readings ranging from 16 to 360 μR/h. The highest measurements were found over structural cracks and seams in the old concrete pad. Some measurements exceed the DOE guideline of 20 μR/h (Table 1) above background for indoor gamma exposure rates.

Alpha and Beta-gamma Activity Levels

Ranges of direct measurements of alpha and beta-gamma activity levels on surfaces inside the metal building were obtained at the same locations where gamma exposure rates were made. Table 4 lists the range and arithmetic average for each grid block. Ranges are shown on Fig. 3. Alpha activity levels ranged from 20 to 18,000 dpm/100 cm^2. The average of all measurements taken on the original concrete pad was 3,200 dpm/100 cm^2 with some grid blocks averaging over 6,000 dpm/100 cm^2. These areas exceeded DOE guidelines for uranium alpha-emitters. Beta-gamma dose rates ranged from background to 2.0 mrad/h with maximum readings on cracks and seams. Areas with measurements exceeding the DOE guideline for maximum dose rate over any 100 cm^2 area were widespread. Analysis of smears disclosed transferable alpha levels ranging from background to 30 dpm/100 cm^2, and removable beta-gamma activities from background levels to 120 dpm/100 cm^2. Only one location was found to have removable alpha and beta-gamma activity levels in excess of guidelines; thus, the contamination is not readily transferable.

CONCRETE PARKING PAD

Gamma Exposure Rate Measurements

Table 5 lists the gamma exposure rate measurements taken at grid locations and the scan readings for grid blocks established over the concrete parking pad (Fig. 4). Grid blocks were sized according to the expansion joints in the concrete pad resulting in blocks

of non-uniform size. Gamma levels at 1 m and at the surface ranged from 5 to 8 μR/h, and 5 to 80 μR/h, respectively. Corresponding overall averages were 7 and 18 μ/R/h, respectively. Scan averages in grid blocks ranged from 6 to 34 μR/h. Widespread contamination throughout the pad was associated with the rust-colored rings presumed to have been deposited with weathering of the metal drums. The highest levels were found at spots having the yellowish crust. Results may be compared to the average measurements of 10 and 13 μR/h at 1 m and at the surface found on the Oak Ridge Reservation (ORR) (Table 2).

A gamma scan outside and around the building and parking pad showed that, generally, exposure rates were 5 to 9 μR/h, with a few areas of elevated readings from 12 to 46 μR/h. The locations of maximum gamma exposure rates measured off the pad are shown on Fig. 4.

Alpha and Beta-gamma Activity Levels

Elevated levels of directly measured alpha activity ranging from 120 to 120,000 dpm/100 cm^2 (Table 6) were found at all rust-colored spots on the pad. Beta-gamma dose rates ranged from 0.04 to 29 mrad/h with the highest measurement generally coinciding with the maximum measured alpha activity. Levels of transferable alpha and beta-gamma were elevated where sampled, ranging from 130 to 6,300 dpm/100 cm^2, and 400 to 1,200 dpm/100 cm^2, respectively. DOE guidelines are exceeded for each category. Because directly measured activity levels were sufficiently elevated for designation of the pad, furthering surveying was discontinued.

A sample of the yellowish residue from the location of maximum removable alpha activity was submitted for isotopic analysis. The results demonstrate that the uranium found on the site is normal rather than enriched.

Soil Sample Analyses

Locations of soil samples taken from areas of elevated gamma levels in parcel 1 are shown on Fig. 4 with results of analyses listed in Table 7. Concentrations of ^{238}U in the top 15-cm layer of soil in 12 samples ranged from <1.1 to 24 pCi/g. Two samples taken from subsurface soil at depths of 15 to 20 cm showed ^{238}U at 15 pCi/g (sample 1B5D) and 80 pCi/g (sample 1B6D). Concentrations of ^{226}Ra ranged from 0.79 to 65 pCi/g in surface samples (0–15 cm), and were 13 and 110 pCi/g in the two subsurface samples (1B5D and 1B6D). DOE guidelines for surface and subsurface soil are exceeded for ^{226}Ra. Two samples were analyzed for ^{230}Th content. The results were 25 pCi/g in surface soil (sample 1B4B) and 0.16 pCi/g in subsurface soil (sample 1B6D). The criterion for concentration

of ^{230}Th in surface soil is exceeded. The Cesium-137 concentrations ranged from <0.063 to 9.9 pCi/g, with only one sample above 1 pCi/g (1B4C). Concentrations of ^{137}Cs are above corresponding ranges found on the ORR in some samples but are below limits which have been suggested for use elsewhere.[4]

PARCEL 2

The survey of this parcel was limited to determining directly measured and transferable alpha and beta-gamma levels on the concrete pad (Fig. 5, Table 8). Locations of measurements sufficiently elevated to indicate designation coincided with rust-colored rings similar to those observed on the parking pad in parcel 1. Total alpha activity levels ranged from 2,200 to 72,000 dpm/100 cm^2. Beta-gamma dose rates ranged from 6.5 to 22 mrad/h at the surface of the pad. These values exceed guidelines. Analysis of smears showed that, although alpha activity levels (90 to 550 dpm/100 cm^2) are below the uranium guideline (Table 1), beta-gamma levels of 470 to 1,200 dpm/100 cm^2 demonstrate that the contamination is transferable.

PARCEL 3

Gamma Exposure Rate Measurements

Although rust-colored stains were not apparent on the concrete pad in parcel 3, a gamma scan disclosed areas of elevated (anomalous) exposure rates. Grid blocks were established along expansion joints as for parcel 1. Scanning results are given in Table 9. Gamma levels generally ranged from 6 to 10 μR/h with isolated, spotty areas of higher measurements (12 to 130 μR/h) restricted to seams and cracks in the concrete (Table 9). Exposure rates were even higher off the pad, 10 mR/h at the surface and 1 mR/h at 1 m near the road in the southwest corner of the parcel at soil sample location 3B2 (Fig. 6).

Soil Sample Analyses

Soil samples 3B1 and 3B2 were collected from two areas off the concrete pad where gamma measurements were elevated (Fig. 6). An exposure rate of 0.1 mR/h was found at sample 3B1 where concentrations of ^{238}U and ^{226}Ra were 28 and 78 pCi/g, respectively, at 0-10 cm (Table 7). That sample was collected on the east side of the pad near a patch of asphalt which had apparently been an entrance to the warehouse formerly in parcel 3. Soil samples 3B2A-E were removed from the area of maximum gamma exposure rate found during the survey and contained the maximum concentrations of radionuclides in sampled soil on the site. Because the high gamma levels indicated very large amounts of radionuclides in surface samples 3B2A and 3B2B, estimates rather than precise analytical results were made for concentrations of ^{238}U and ^{226}Ra in those samples. The ratios of

analytical results in pCi/g for samples 3B2C-E to directly measured gamma exposure rates in kcpm at the surface of each of those samples were averaged. The resulting conversion factor was used to derive estimated concentrations as follows (pCi/g):

Sample	Depth (cm)	^{238}U	^{226}Ra
3B2A	0-5	1,500	1,300
3B2B	5-10	5,300	4,600

Concentrations of ^{238}U in samples 3B2C-E ranged from 130 pCi/g at 46-51 cm, to 920 pCi/g at 15-30 cm (Table 7). Corresponding concentrations of ^{226}Ra ranged from 95 to 830 pCi/g, respectively. These values exceed the DOE surface and subsurface criteria for ^{226}Ra. One surface sample was anaylzed for ^{230}Th and contained 22 pCi/g. This value exceeds the criterion of 5 pCi/g above background in the top 15 cm of soil. Concentrations of ^{137}Cs ranged from 0.77 to 2.3 pCi/g, values below the suggested guideline of 80 pCi/g shown in Table 1.

PARCEL 4

Gamma Exposure Rate Measurements

Measurements on the concrete pad in parcel 4 revealed a range of gamma exposure rates from 5 to 9 μR/h with no anomalous areas. However, elevated gamma readings with a maximum of 120 μR/h at the surface were detected outside the pad at 8 locations and were sampled for radionuclide content (Fig. 7). Gamma exposure rates associated with a subsurface sample (4B7) collected beneath the asphalt entrance to the parcel 3 warehouse at a depth of 13 to 28 cm were 520 μR/h. Readings on the asphalt surface above the sample were 34 μR/h, and at 28 cm below the surface were 370 μR/h. Spillover to parcel 5 is indicated by elevated gamma levels at the boundary line as shown on Fig. 7.

Soil Sample Analyses

Concentrations of ^{238}U in surface samples (0-15 cm) ranged from 16 to 250 pCi/g (Table 7). Subsurface concentrations of ^{238}U were 8.3 to 140 pCi/g. Radium-226 was found in surface samples at concentrations of 21 to 600 pCi/g. Concentrations of 2.5 to 320 pCi/g were measured in samples collected from depths of 13-30 cm. The maximum concentration of ^{226}Ra in a subsurface sample (320 pCi/g) was found in gravel and dirt at 13 to 28 cm beneath the asphalt entrance to the warehouse formerly in parcel 3. Values for ^{226}Ra are in excess of guidelines (Table 1). The concentration of ^{230}Th was 0.54 pCi/g in subsurface soil sample 4B6B, a value below the criterion of 15 pCi/g above background in any 15-cm layer below the top 15 cm. Cesium-137 concentrations were <0.5 pCi/g in all samples.

SIGNIFICANCE OF FINDINGS

Survey results show that widespread residual radioactivity from former operations remain at the former warehouse area at Elza Gate. The primary contaminants are ^{238}U and ^{226}Ra occurring in outdoor soil and as surface contamination on three of the original concrete pads, one of which is inside the present building. The survey was limited in extent since preliminary results indicated that radiation levels exceed DOE guidelines in parcels 1 through 4. The results of this survey suggest that spillover contamination to parcels 5 through 9 is probable and that further investigations should be conducted to characterize the full extent of the contamination.

PARCEL 1 — Although some values inside the building in parcel 1 exceed the DOE guideline for indoor gamma exposure rates of 20 μR/h above background (Table 1), the average exposure rates, particularly at the critical height of 1 m, would not pose a significant radiation exposure hazard to personnel. Directly measured surface contamination, especially alpha activity levels, was widespread with many measurements in excess of DOE guidelines. Analyses of smear samples demonstrated that the contamination is not readily transferable. Because the elevated areas are limited to isolated spots at the surface associated with cracks and seams in the original concrete pad, it is highly unlikely that any individual working in or frequenting the building would receive a significant radiation exposure.

Outdoors in parcel 1, gamma exposure rates were generally low (5 to 8 μR/h) but elevated levels to a maximum of 80 μR/h were measured on and around the concrete parking pad surface. The highest measurements were associated with a yellowish crust over rust-colored stains where residuals appear to have leaked from storage drums. All stains exhibited elevated alpha and beta-gamma measurements, both fixed and transferable. Soil sampling at the elevated areas off the pad showed that concentrations of ^{230}Th in surface soil, and ^{226}Ra in both surface and subsurface soil are higher than DOE guidelines (Table 1). The maximum concentration of ^{137}Cs in any soil sample from the site (9.9 pCi/g) was taken from this parcel and is below other site specific cleanup criteria derived for other FUSRAP sites (30 to 80 pCi/g) and below the 80 pCi/g limit suggested by Healy et al. (1983).[4]

PARCEL 2 — Elevated measurements were also associated with rust-colored stains on the surface of the concrete pad in this parcel. Maximum directly measured alpha activity levels were 72,000 dpm/100 cm^2, a factor of >14 times the guideline for ^{238}U (Table 2). Beta-gamma dose rates were 20 times the maximum allowable limit in any 100 cm^2 area.

PARCEL 3 — The concrete pad in parcel 3 had none of the contaminated stains apparently associated with leakage from storage drums. However, elevated gamma exposure rates were found both on and off the pad. Contamination on the pad was confined to seams and cracks in the concrete. Two areas off the pad displayed the highest gamma exposure rates measured during the survey, 0.1 and 10 mR/h. Soil samples from the area of maximum gamma contained the highest concentrations of ^{238}U and ^{226}Ra found on the site (5,300 and 4,600 pCi/g, respectively).

PARCEL 4 — A gamma scan revealed no anomalies on the concrete pad. Several elevated areas were found off the pad, however, with gamma levels ranging from 12 to 120 μR/h. These areas were associated with the apparent remains of an entrance to the warehouse that had stood on the concrete pad in parcel 3. Soil sampling in the areas of anomalous gamma levels demonstrated radionuclides in concentrations exceeding guidelines. Elevated exposure rates at the boundary between parcels 4 and 5 indicate that the adjoining parcels may also be contaminated.

In summary, concentrations of residual radioactive material found on surfaces and in soil on the site are in excess of DOE FUSRAP criteria. These guidelines are typically derived to ensure that unrestricted use of the property (including residential use) will not result in above-guideline doses to the general public. Because results indicate probable spillover of residuals to parcels 5 through 9, additional surveying to include those areas is recommended.

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2. A. Wallo III, Office of Nuclear Energy, Germantown, Maryland, letter to W. D. Cottrell, Oak Ridge National Laboratory, Oak Ridge, Tennessee, March 30, 1987.

3. T. E. Myrick, B. A. Berven, W. D. Cottrell, W. A. Goldsmith, and F. F. Haywood, *Procedures Manual for the ORNL Radiological Survey Activities (RASA) Program,* Oak Ridge National Laboratory, Oak Ridge, Tennessee, ORNL/TM-8600 (April 1987).

4. J. W. Healy, J. C. Rodgers, and C. L. Wienke, *Interim Soil Limits for D&D Projects,* Los Alamos Scientific Laboratory, LA-UR-79-1865-Rev., Los Alamos, N.M. (1979). Cited in U.S. Department of Energy, *Radiological Guidelines for Application to DOE's Formerly Utilized Sites Remedial Action Program,* Oak Ridge Operations, ORO-831 (March 1983).

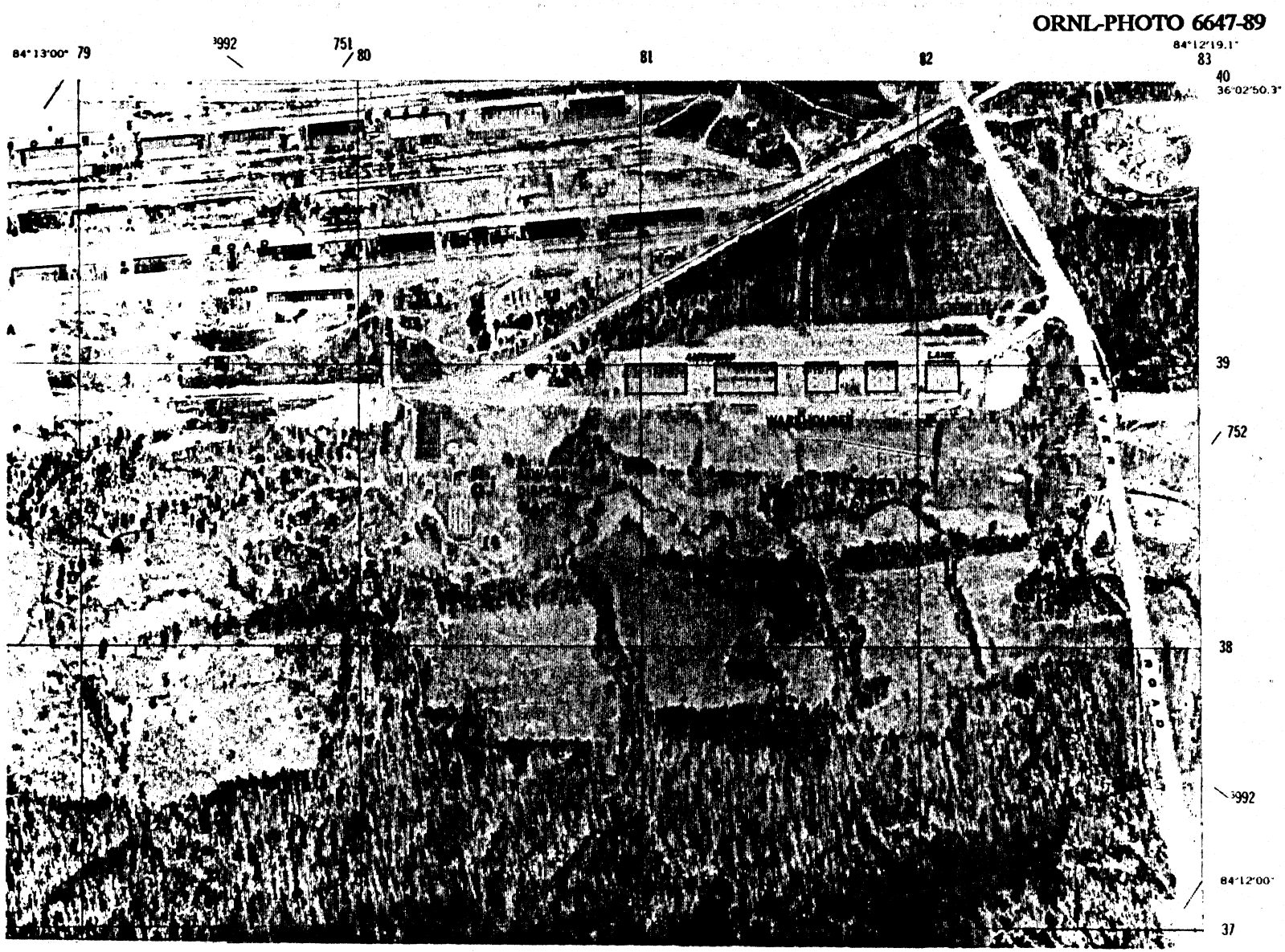

Fig. 1. Aerial photo (1943) of the former Oak Ridge Warehouse Area at Elza Gate, showing warehouse locations.

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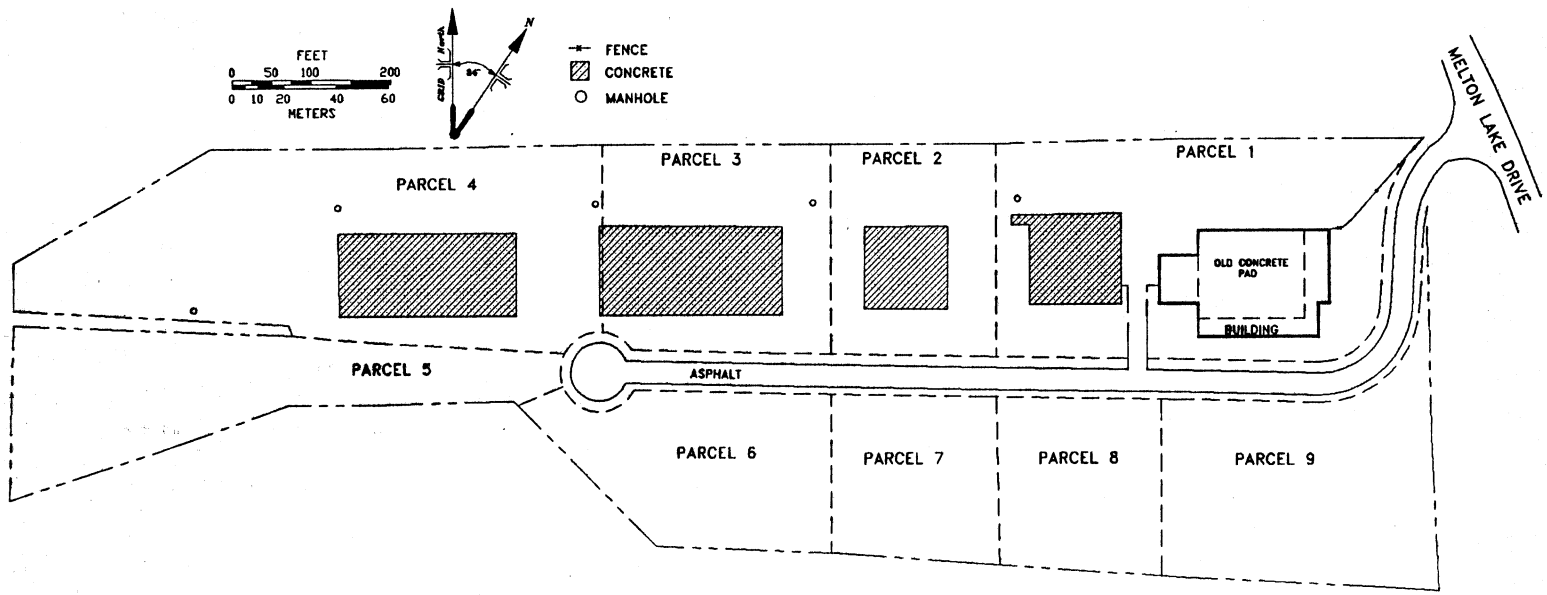

Fig. 2. Drawing showing layout of the former Elza Gate Warehouse site.

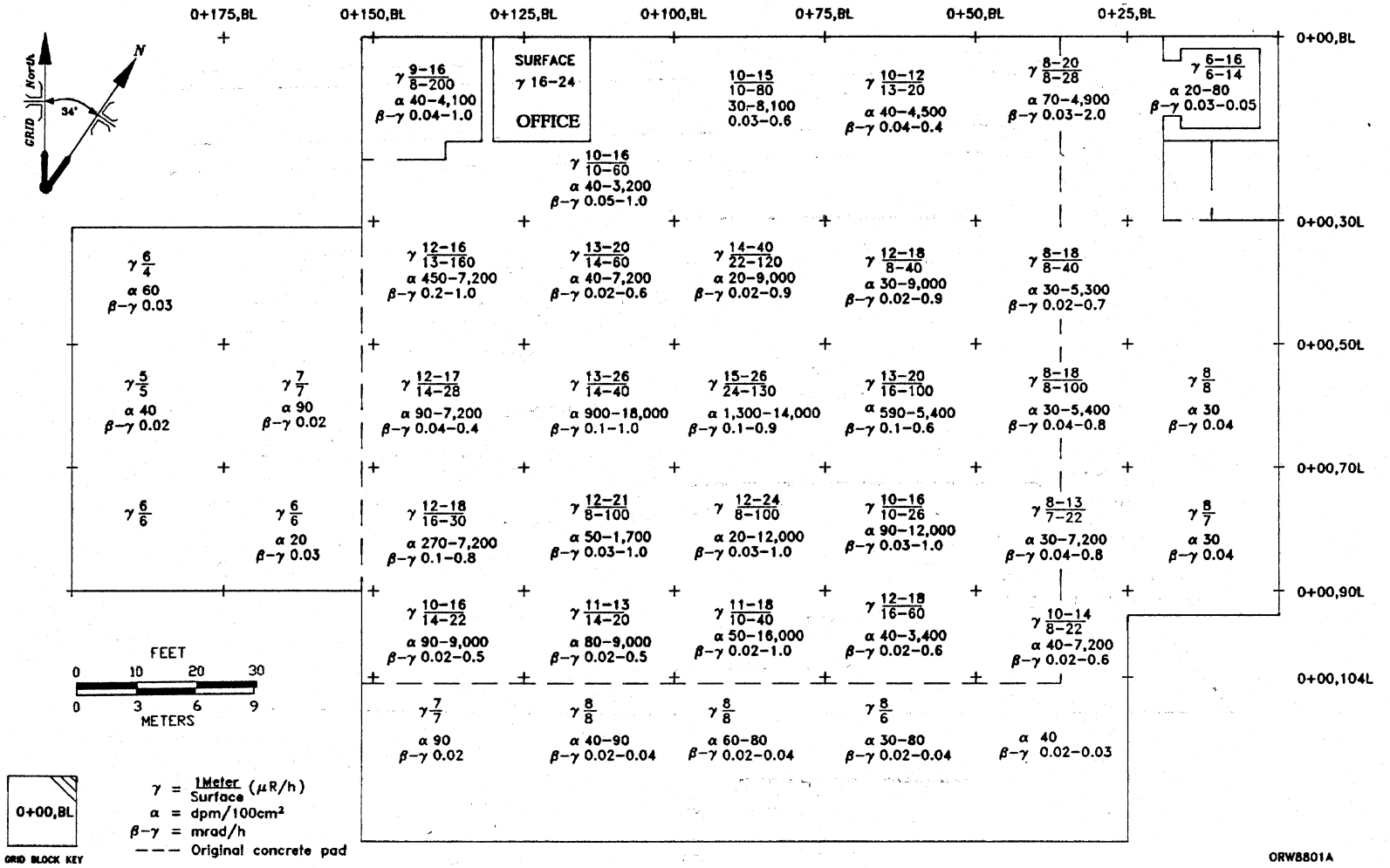

Fig. 3. Diagram of the parcel 1 building with grid system and indoor grid block measurements (all readings were direct).

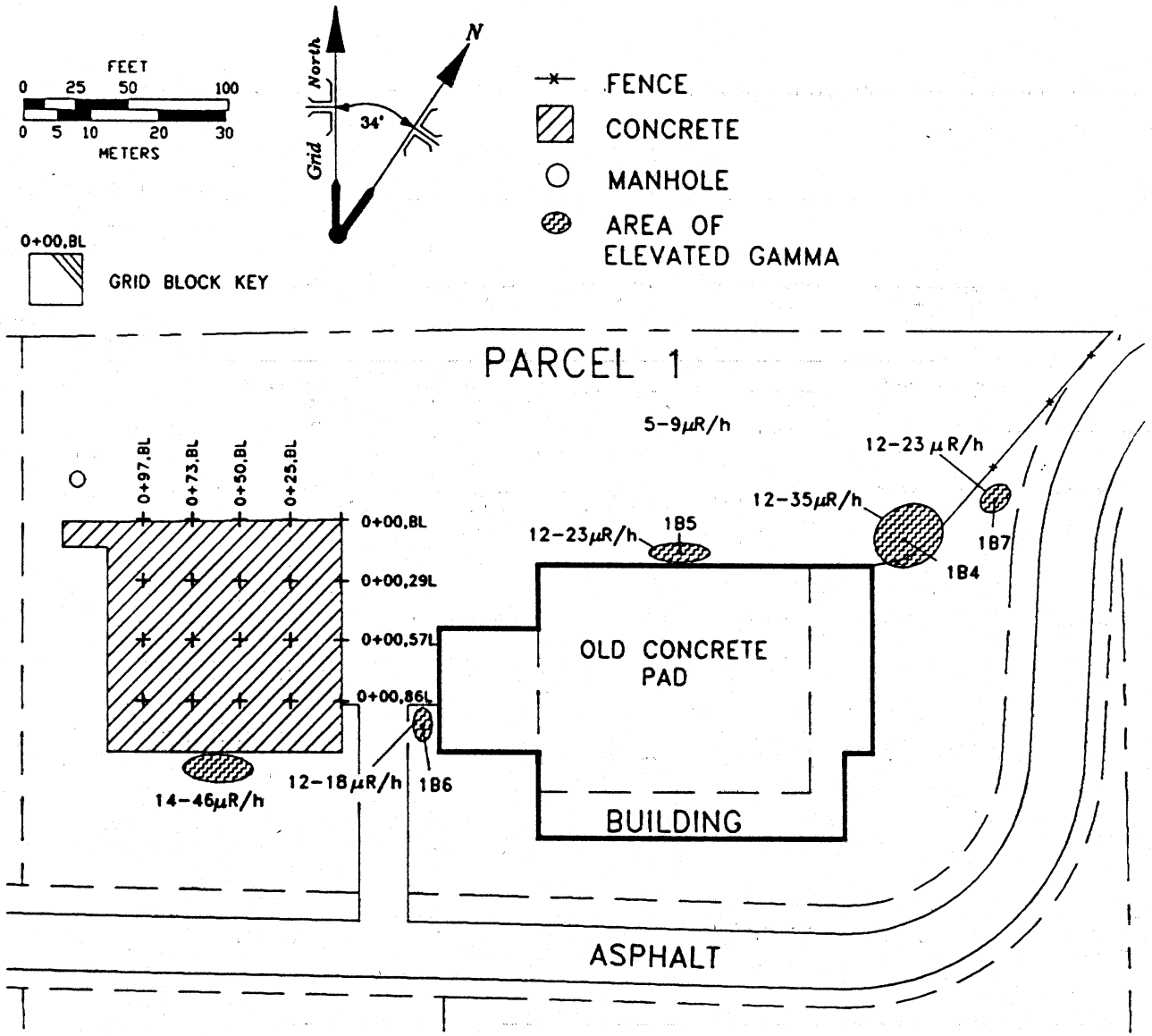

Fig. 4. Parcel 1 showing locations of soil samples and outdoor areas of elevated gamma exposure rates.

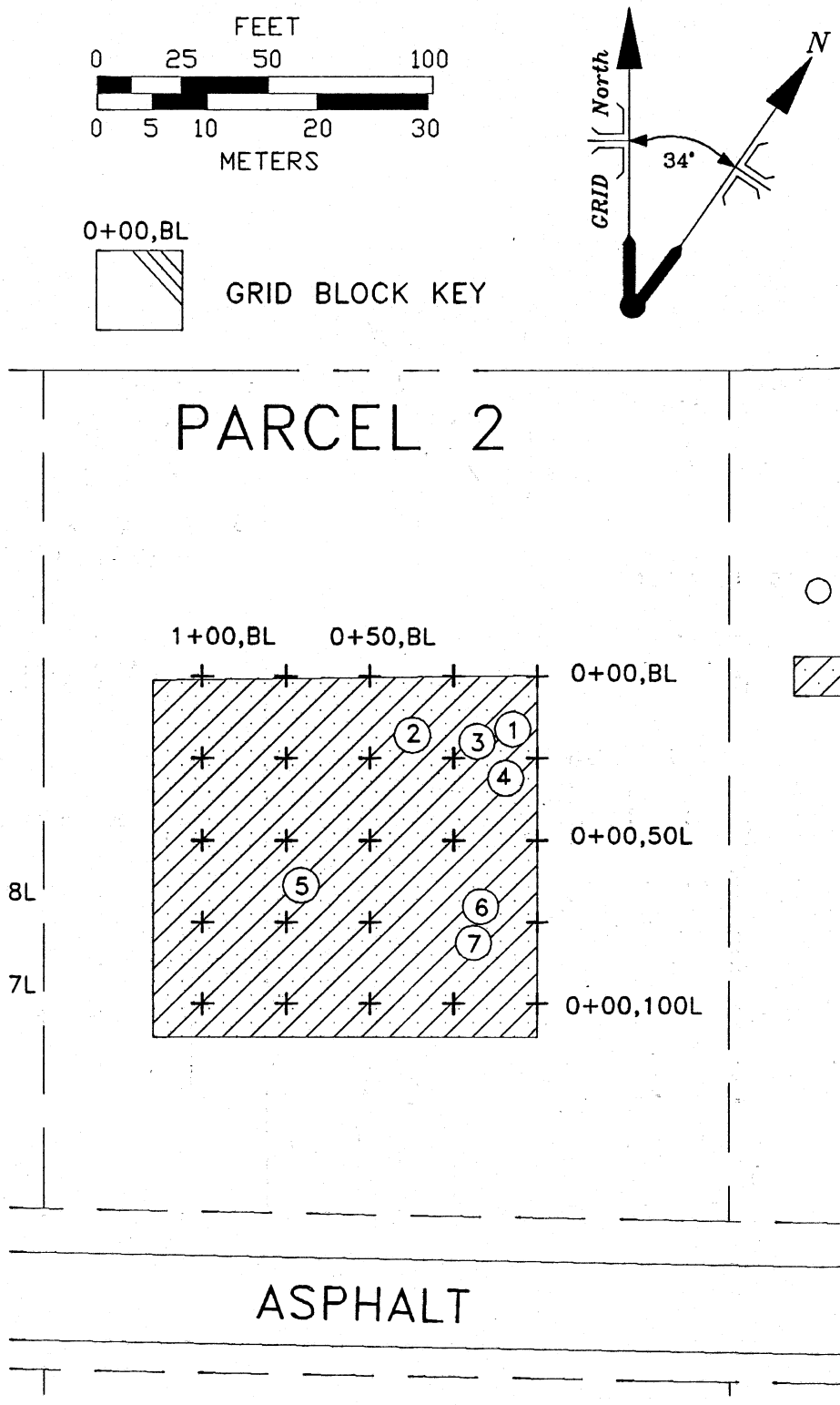

Fig. 5. Parcel 2 showing grid system and areas of elevated directly measured alpha activity levels (circled numbers correspond to those in Table 8).

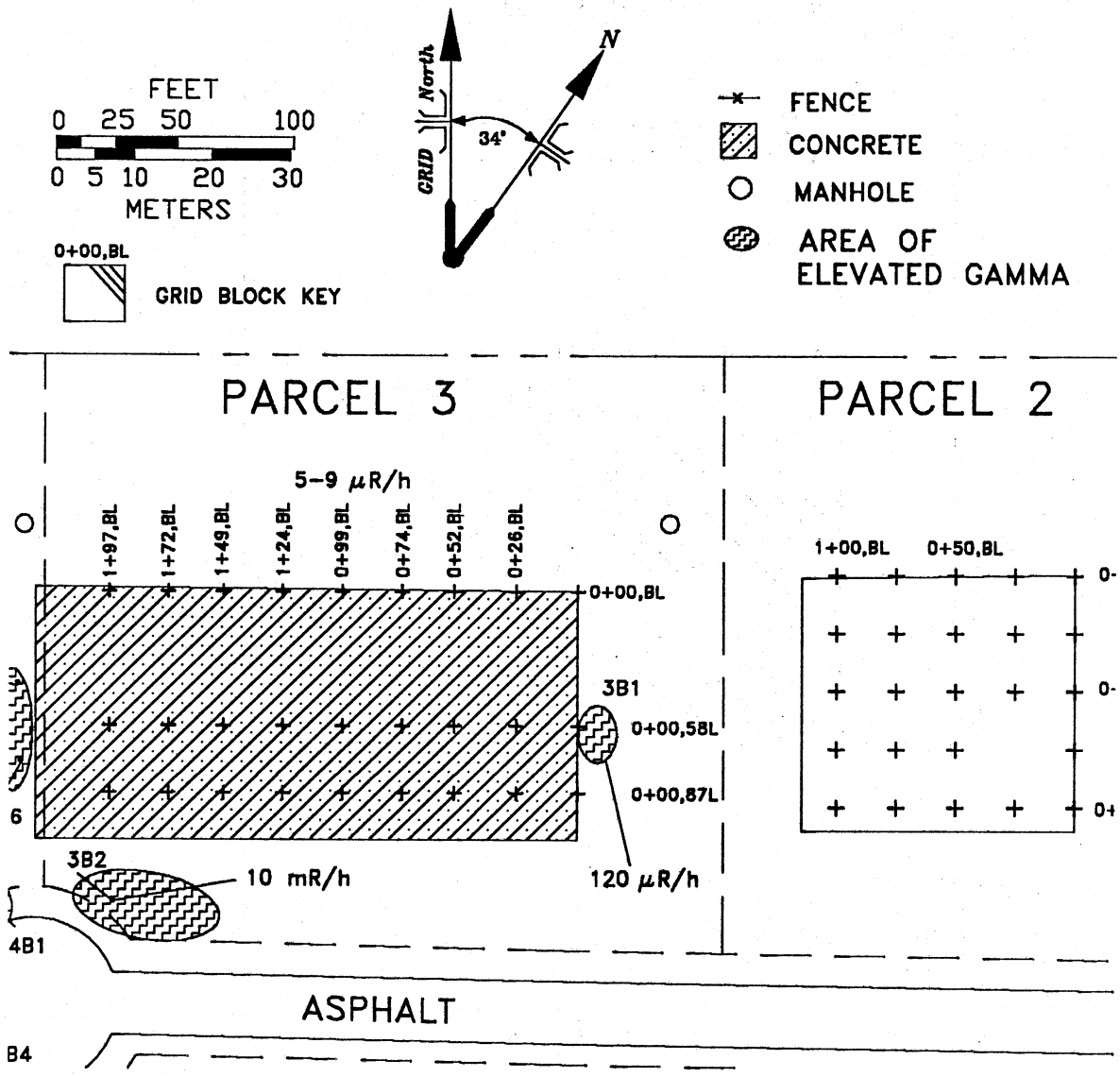

Fig. 6. Parcel 3 showing grid, soil sample locations, and areas of elevated gamma exposure rate measurements.

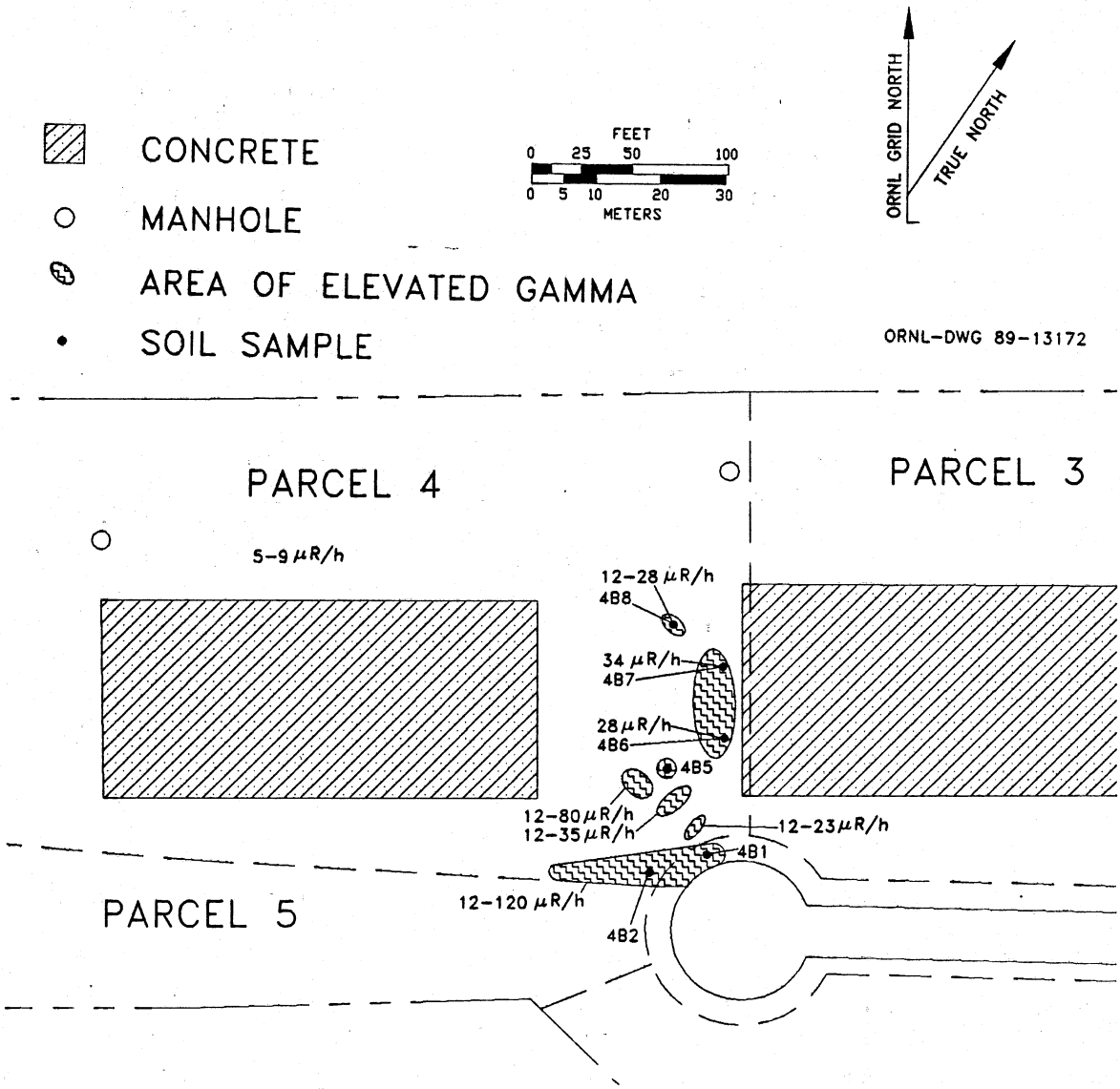

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Fig. 7. Parcel 4 showing soil sample locations and areas of elevated gamma exposure rate measurements.

Table 1. Applicable guidelines for protection against radiation

Mode of exposure	Exposure conditions	Guideline value
Gamma radiation[a]	Indoor gamma radiation level (above background)	20 μR/h
Surface contamination[a]	^{238}U, U-natural	
	Fixed on surfaces	5000 dpm/100 cm^2
	Removable	1000 dpm/100 cm^2
	^{232}Th, Th-natural	
	Fixed on surfaces	1000 dpm/100 cm^2
	Removable	200 dpm/100 cm^2
	^{226}Ra	
	Fixed on surfaces	100 dpm/100 cm^2
	Removable	20 dpm/100 cm^2
Beta-gamma dose rates[b]	Surface dose rate averaged over not more than 1 m^2	0.20 mrad/h
	Maximum dose rate in any 100 cm^2	1.0 mrad/h
Radionuclide concentrations in soil[a]	Maximum permissible concentration of the following radionuclides in soil above background levels averaged over 100 m^2 area ^{232}Th ^{230}Th ^{228}Ra ^{226}Ra	5 pCi/g averaged over the first 15-cm of soil below the surface; 15 pCi/g when averaged over 15-cm thick soil layers more than 15 cm below the surface
	^{238}U	Derived (site specific)
	Concentration limit in surface soil above background levels based on dose estimates from major exposure pathways[c] ^{137}Cs	80 pCi/g over a 100 cm^2 area of contamination

[a]U.S. Department of Energy, *Guidelines for Residual Radioactivity at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites* (April 1987).

[b]Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except ^{90}Sr, ^{228}Ra, ^{223}Ra, ^{227}Ac, ^{133}I, ^{131}I, ^{129}I, ^{126}I, ^{125}I.

[c]J. W. Healy, J. C. Rodgers, and C. L. Wienke, *Interim Soil Limits for D&D Projects,* Los Alamos Scientific Laboratory, LA-UR-79-1865-Rev., Los Alamos, N.M. (1979). Cited in U.S. Department of Energy, *Radiological Guidelines for Application to DOE's Formerly Utilized Sites Remedial Action Program,* Oak Ridge Operations, ORO-831 (March 1983).

Table 2. Gamma radiation levels and concentrations of selected radionuclides in soil samples taken on the Oak Ridge Reservation

Type of radiation measurement or sample	Radiation level or radionuclide concentration	
	Range	Average
Gamma exposure rate at 1 m above ground surface (μR/h)[a]	8–13	10
Gamma exposure rate at ground surface (μR/h)[a]	10–17	13
Concentration of radionuclides in soil (pCi/g dry wt)[b]		
^{137}Cs	0.04–2.6	0.77
^{226}Ra	0.40–1.3	0.93
^{238}U	0.53–1.5	1.0

[a]Values were obtained from 18 measurements taken from 9 locations on the Oak Ridge Reservation.

[b]Values for ^{137}Cs and ^{226}Ra were obtained by gamma spectrometry analysis of 12 soil samples taken from 3 locations on the Oak Ridge Reservation. Values for ^{238}U were obtained by neutron activation analysis of 21 soil samples taken from 6 locations on the Oak Ridge Reservation.

Table 3. Results of gamma exposure rate measurements inside the building in parcel 1 at the former Elza Gate Warehouse Area

Grid block[a]	Gamma exposure rate at 1 m (μR/h)[b]		Gamma exposure rate at surface (μR/h)[b]	
	Average	Range	Average	Range
0+00, BL	8	6-16	8	6-14
0+25, BL	14	8-20	18	8-28
0+50, BL	11	10-12	15	13-20
0+75, BL	12	10-15	26	10-80
0+100, BL	14	10-16	24	10-60
0+125, BL	11	9-16	55	8-200
0+25, 30L	15	8-18	26	8-40
0+50, 30L	15	12-18	28	8-40
0+75, 30L	22	14-40	50	22-120
0+100, 30L	16	13-20	85	14-60
0+125, 30L	14	12-16	51	13-160
0+175, 30L	c	6	c	4
0+00, 50L	c	8	c	8
0+25, 50L	14	8-18	30	8-100
0+50, 50L	16	13-20	31	16-100
0+75, 50L	20	15-26	69	24-130
0+100, 50L	19	13-26	22	14-40
0+125, 50L	13	12-17	20	14-28
0+150, 50L	c	7	c	7
0+175, 50L	c	5	c	5
0+00, 70L	c	8	c	7
0+25, 70L	12	8-13	17	7-22
0+50, 70L	14	10-16	20	10-26
0+75, 70L	17	12-24	32	8-100
0+100, 70L	17	12-21	42	8-100
0+125, 70L	16	12-18	26	16-30
0+150, 70L	c	6	c	6
0+175, 70L	c	6	c	6
0+25, 90L	12	10-14	15	8-22
0+50, 90L	14	12-18	28	16-60
0+75, 90L	17	11-18	24	10-40
0+100, 90L	12	11-13	17	14-20
0+125, 90L	12	10-16	18	14-22
0+25, 104L	8	c	6	c
0+50, 104L	c	8	c	6
0+75, 104L	c	8	c	8
0+100, 104L	c	8	c	8
0+125, 104L	c	7	c	7
Office	c	c	c	16-24

[a]Location shown on Fig. 3.
[b]Each range and average represents the cumulative results for 5-10 measurements.
[c]Only one measurement in this grid block was taken.

Table 4. Directly measured alpha and beta-gamma activity levels inside the building in parcel 1 at the former Elza Gate Warehouse Area

Grid block[a]	Alpha (dpm/100 cm^2)		Beta-gamma dose rate at 1 cm (mrad/h)	
	Average	Range	Average	Range
0+00, BL	40	20–80	0.04	0.03–0.05
0+25, BL	2,100	70–4,900	0.3	0.03–2.0
0+50, BL	2,200	40–4,500	0.2	0.04–0.4
0+75, BL	2,400	30–8,100	0.03	0.03–0.6
0+100, BL	1,900	40–3,200	0.3	0.05–1.0
0+125, BL	2,000	40–4,100	0.6	0.04–1.0
0+25, 30L	2,000	30–5,300	0.4	0.02–0.7
0+50, 30L	2,000	30–9,000	0.3	0.02–0.9
0+75, 30L	2,700	20–9,000	0.2	0.02–0.9
0+100, 30L	2,400	40–7,200	0.3	0.02–0.6
0+125, 30L	3,100	450–7,200	0.5	0.2 –1.0
0+175, 30L	*c*	60	*c*	0.03
0+00, 50L	*c*	30	*c*	0.04
0+25, 50L	1,600	30–5,400	0.4	0.04–0.8
0+50, 50L	2,800	590–5,400	0.3	0.1 –0.6
0+75, 50L	6,700	1300–14,000	0.5	0.1 –0.9
0+100, 50L	6,100	900–18,000	0.3	0.1 –1.0
0+125, 50L	2,600	90–7,200	0.04	0.04–0.4
0+150, 50L	*c*	90	*c*	0.02
0+175, 50L	*c*	40	*c*	0.02
0+00, 70L	*c*	30	*c*	0.04
0+25, 70L	3,400	30–7,200	0.4	0.04–0.8
0+50, 70L	5,000	90–12,000	0.6	0.03–1.0
0+75, 70L	3,900	20–12,000	0.8	0.03–1.0
0+100, 70L	6,900	50–1,700	0.6	0.03–1.0
0+125, 70L	3,900	270–7,200	0.4	0.1 –0.8
0+150, 70L	*c*	20	*c*	0.03
0+25, 90L	2,300	40–7,200	0.2	0.02–0.6
0+50, 90L	1,600	40–3,400	0.3	0.02–0.6
0+75, 90L	5,400	50–16,000	0.5	0.02–1.0
0+100, 90L	2,200	80–9,000	0.2	0.02–0.5
0+125, 90L	3,000	90–9,000	0.3	0.02–0.5
0+25, 104L	*c*	40	0.02	0.02–0.03
0+50, 104L	50	30–80	0.03	0.02–0.04
0+75, 104L	80	60–80	0.03	0.02–0.04
0+100, 104L	60	40–90	0.03	0.02–0.04
0+125, 104L	*c*	90	*c*	0.02

[a]Location shown on Fig. 3.
[b]Each range and average represents the cumulative results for 5–10 measurements.
[c]Only one measurement was obtained at this location.

Table 5. Gamma exposure rate measurements over the parking pad in parcel 1 at the former Elza Gate Warehouse Area

Grid block[a]	Gamma exposure rates during scan of grid block (μR/h)		Grid location measurements (μR/h)		
	Range	Average	Grid location[a]	at 1 m	at surface
0+00, BL	6-7	6	0+85, BL	7	69
0+25, BL	5-7	6	0+48, 2L	6	6
0+50, BL	6-58	9	0+31, 4L	6	6
0+73, BL	6-69	13	0+72, 4L	7	6
0+97, BL	6-9	7	0+05, 6L	6	5
0+00, 29L	7-21	12	0+17, 6L	5	6
0+25, 29L	7-21	12	0+69, 7L	8	58
0+50, 29L	7-23	14	0+65, 10L	6	28
0+73, 29L	9-51	30	0+54, 21L	7	6
0+97, 29L	7-23	12	0+67, 21L	8	28
0+00, 57L	9-53	12	0+19, 22L	6	6
0+25, 57L	8-15	10	0+30, 23L	6	7
0+50, 57L	7-23	9	0+46, 23L	8	9
0+73, 57L	9-23	14	0+06, 24L	5	6
0+97, 57L	9-46	12			
0+00, 86L	6-69	8			
0+25, 86L	7-12	9			
0+50, 86L	7-14	9			
0+73, 86L	9-80	34			
0+97, 86L	12-34	23			

[a]Location shown on Fig. 4.

Table 6. Alpha and beta-gamma activity levels measured on the surface of the concrete parking pad in parcel 1 at the former Elza Gate Warehouse Area

	Directly measured contamination		Transferable contamination	
Grid location[a]	Alpha (dpm/100 cm^2)	Beta-gamma dose rates at 1 cm (mrad/h)	Alpha (dpm/100 cm^2)	Beta-gamma (dpm/100 cm^2)
0+85, BL	120,000	22	*b*	*b*
0+86, BL	110,000	*b*	6,300	620
0+48, 2L	130	0.05	*b*	*b*
0+31, 4L	220	0.04	*b*	*b*
0+72, 4L	99,000	11	*b*	*b*
0+05, 6L	120	0.04	*b*	*b*
0+17, 6L	160	0.05	*b*	*b*
0+69, 7L	110,000	29	*b*	*b*
0+69, 8L	120,000	*b*	*b*	*b*
0+65, 10L	90,000	5.3	*b*	*b*
0+86, 12L	110,000	*b*	4,000	1,200
0+54, 21L	360	0.05	*b*	*b*
0+67, 21L	86,000	7.3	*b*	*b*
0+19, 22L	200	0.1	*b*	*b*
0+30, 23L	1100	0.07	*b*	*b*
0+46, 23L	7,200	0.2	*b*	*b*
0+06, 24L	220	0.09	*b*	*b*
0+12, 96L	23,000	*b*	130	400

[a]Location shown on Fig. 4.

[b]No measurement taken.

Table 7. Concentrations of radionuclides in soil samples collected at the former Elza Gate Warehouse Area

Sample[a]	Depth (cm)	Radionuclide concentration (pCi/g)			
		^{238}U[b]	^{230}Th[b]	^{226}Ra[b]	^{137}Cs[b]
1B4A	0–5	13 ± 4	c	41 ± 0.3	0.65 ± 0.07
1B4B	5–10	24 ± 6	25 ± 1	65 ± 0.3	0.31 ± 0.06
1B4C	10–15	20 ± 4	c	29 ± 0.3	9.9 ± 0.09
1B5A	0–5	<9.6	c	13 ± 0.2	0.32 ± 0.05
1B5B	5–10	<7.0	c	28 ± 0.3	<0.12
1B5C	10–15	<11.0	c	21 ± 0.2	0.43 ± 0.03
1B5D	15–20	15 ± 5	c	13 ± 0.2	0.097 ± 0.05
1B6A	0–5	0.92 ± 0.3	c	1.4 ± 0.02	0.062 ± 0.006
1B6B	5–10	2.1 ± 1.0	c	5.5 ± 0.06	0.081 ± 0.03
1B6C	10–15	6.0 ± 2	c	29 ± 0.1	0.066 ± 0.04
1B6D	15–20	80 ± 12	0.16 ± 0.003	110 ± 0.6	0.61 ± 0.1
1B7A	0–5	<1.1	c	0.79 ± 0.02	0.28 ± 0.01
1B7B	5–10	5.8 ± 3	c	20 ± 0.2	0.11 ± 0.06
1B7C	10–15	11 ± 5	c	23 ± 0.2	<0.063
3B1	0–10	28 ± 11	22 ± 0.8	78 ± 0.4	0.77 ± 0.1
3B2C	15–30	920 ± 38	c	830 ± 2	1.3 ± 0.4
3B2D	30–46	420 ± 44	c	400 ± 2	1.1 ± 0.5
3B2E	46–51	130 ± 7	c	95 ± 0.6	2.3 ± 0.1
4B1A	0–15	16 ± 1.0	c	21 ± 0.06	0.21 ± 0.02
4B1B	15–30	8.3 ± 2	c	7.0 ± 0.06	0.14 ± 0.02
4B2	0–15	200 ± 21	c	600 ± 10	<0.32
4B3A	0–10	250 ± 36	c	390 ± 2	<0.47
4B3B	10–20	140 ± 7	c	290 ± 1.0	<0.33
4B4	0–15	65 ± 11	c	130 ± 0.5	<0.16
4B5	0–15	33 ± 5	c	98 ± 0.4	0.28 ± 0.09
4B6A	0–15	38 ± 7	c	120 ± 0.5	0.16 ± 0.1
4B6B	15–30	19 ± 2	0.54 ± 0.14	2.5 ± 0.02	0.036 ± 0.01
4B7	13–28	130 ± 16	c	320 ± 1.0	<0.40
4B8A	0–15	33 ± 4	c	50 ± 0.3	<0.092
4B8B	15–25	22 ± 2	c	8.4 ± 0.06	<0.030

[a]Locations of soil samples are shown on Fig. 4.
[b]Indicated counting error is at the 95% confidence level (±2σ).
[c]No analysis performed.

Table 8. Alpha and beta-gamma activity levels measured on the surface of the concrete pad in parcel 2 at the former Elza Gate Warehouse Area

Grid location[a]	Directly measured contamination		Transferable contamination	
	Alpha (dpm/100 cm^2)	Beta-gamma dose rates at 1 cm (mrad/h)	Alpha (dpm/100 cm^2)	Beta-gamma (dpm/100 cm^2)
(1) 0+04, 16L	22,000	22	*b*	*b*
(2) 0+35, 18L	72,000	22	550	1,200
(3) 0+23, 23L	27,000	18	*b*	*b*
(4) 0+09, 30L	2,200	6.5	*b*	*b*
(5) 0+74, 68L	45,000	14	500	770
(6) 0+17, 74L	40,000	22	*b*	*b*
(7) 0+18, 86L	11,000	12	90	470

[a](n)=location shown on Fig. 5.

[b]No measurement taken.

Table 9. Gamma exposure rate measurements on the concrete pad in parcel 3 at the former Elza Gate Warehouse Area

Grid block[a]	Grid block measurements (μR/h)		Anomalous exposure rates during scan of grid block (μR/h)	
	Range	Average	Gamma	Location
0+26, 58L	6-8	7	-	-
0+52, 58L	6-8	7	-	-
0+74, 58L	6-9	7	-	-
0+99, 58L	6-8	7	18-28	cracks
1+49, 58L	6-9	7	92-100	spots, cracks
0+00, 87L	6-8	7	-	-
0+26, 87L	6-8	7	-	-
0+52, 87L	8-12	9	58	near dock
0+74, 87L	8-12	9	12	in crack, S end
0+99, 87L	7-10	9	58	spot
1+24, 87L	7-14	9	12-14	on crack, S end
1+49, 87L	6-12	8	-	-
1+72, 87L	7-12	9	69; 130	spot; 8-in. crack
1+97, 87L	6-10	8	-	-

[a]Location shown on Fig. 6.

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